Development and Management Aspects of Irrigation and Drainage Systems

Proceedings of the Specialty Conference
Sponsored by the Irrigation and Drainage Division
of the American Society of Civil Engineers and the
San Antonio Branch and Texas Section of ASCE

Hilton Palacio Del Rio Hotel
San Antonio, Texas
July 17-19, 1985

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Edited by Conrad G. Keyes, Jr. and Tim J. Ward

Published by the
American Society of Civil Engineers
345 East 47th Street
New York, New York 10017-2398

ANNUAL AND SEASONAL VARIATIONS OF PHOSPHORUS LOADS IN THE OKANAGAN RIVER

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ABSTRACT

Results of monitoring of phosphorus loads in the Okanagan River channel linking Okanagan, Skaha and Osoyoos Lakes are described. The southern Okanagan basin is the area where major changes in phosphorus loads from the Penticton waste water treatment plant were anticipated. Consistent changes in river loadings occurred above the inlet to Skaha Lake. The surface loading rates of phosphorus to this lake decreased from 8.92 to 3.57 acre^{-1} yr^{-1} (1 to 0.4 g m^{-2} yr^{-1}) between 1970 to 1980. The reduction in phosphorus loads from the Penticton plant is not apparent below this lake because diffuse source loadings are increasing downstream. The surface loading of phosphorus to Osoyoos Lake, in the amount of 12.49 lb acre^{-1} yr^{-1} (1.4 g m^{-2} yr^{-1}), remains in 1980, above the critical loading rate as it was in 1970.

INTRODUCTION

A monitoring program of nutrient loads was carried out by the Water Quality Branch, Inland Waters Directorate, as part of the Canada-British Columbia Okanagan Basin Implementation Agreement, during the period from 1976 to 1980 (4). This program was designed to estimate nutrient loads with 95% confidence limits, and to assess the effectiveness of remedial actions, undertaken in 1971, to reduce phosphorus loads from the effluent of the Penticton waste treatment plant. The present article summarizes results of the monitoring of phosphorus loads in the Okanagan River at the outlet of Okanagan Lake, at the inlet and outlet of Skaha Lake, and at the inlet to Osoyoos Lake.

STUDY AREA

The Okanagan Basin is located in a semi arid region of southern British Columbia. The total population was 185,000 in 1981 and continues to grow (4). The requirement for irrigation of more than 61,775 acres (25,000 ha) accounts for over 75% of the total consumptive use (4). The agricultural productivity of the irrigated land is increasing through the intensive use of fertilizers, higher density of plantings in vineyards and orchards and the application of pesticides.

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PREVIOUS STUDY

In 1970, prior to remedial actions, the loads of phosphorus contributing to eutrophication of Skaha Lake (1), in the amount of 79.12 lb day^{-1} (35.89 kg day^{-1}) and 37.15 lb day^{-1} (16.85 kg day^{-1}), came from the Penticton municipal outfall and from diffuse sources, respectively. The amounts of phosphorus loads, estimated at the station above Osoyoos Lake were 10.87 lb day^{-1} (4.93 kg day^{-1}) from the Oliver waste water treatment plant, and 61.01 lb day^{-1} (27.67 kg day^{-1}) from diffuse sources. The annual mean discharge in 1970 in the Okanagan River into Osoyoos Lake of 293 cfs (8.3 m^3 sec^{-1}), was below the normal range of 618 cfs (17.5 m^3 sec^{-1}), (2).

MATERIALS AND METHODS

Sampling stations for chemical analysis of water samples (Figure 1) were located in the reaches of the Okanagan River below Okanagan Lake (Station 1), above and below Skaha Lake (Stations 2 and 3), and above Osoyoos Lake (Station 4). The selection of these stations, based on the examination of lateral and vertical mixing of nutrients in the channel cross-section is described in (8). Two sampling strategies were used: (a) simultaneous, and (b) sequential sampling (7).

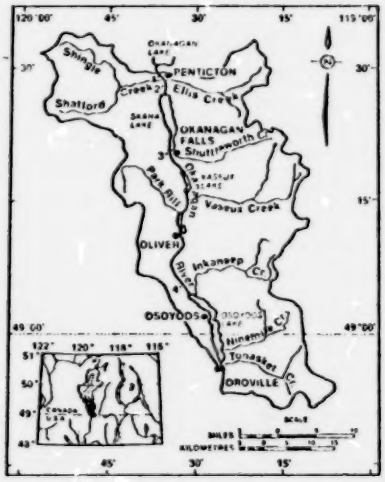

FIG. 1. - Southern part of the Okanagan River Basin. Hydrometric stations (1, 3, and 4) and Water Quality Sampling Sites (1, 2, 3 and 4).

The simultaneous sampling, employing a manual-replicate sampler across the channel, was used for the estimation of loads by the partial

load method (9). The sequential sampling, employing an automatic device to obtain a series of point concentration measurements, was used to estimate loads by the flow interval method (12). A correlation significant, at the 95% level, was achieved between the estimates obtained by the partial load and flow interval methods. The estimates shown in the present study are, therefore, based on the combination of results derived from these two methods.

RESULTS AND DISCUSSION

Most of the monthly discharges in the Okanagan River were above the normal range in 1976 and 1978, and below this range in 1977, 1979 and 1980 (2). The highest annual mean discharge of 858 cfs (24.3 m^{-3} sec^{-1}) and lowest mean discharge of 285 cfs (8.07 m^3 sec^{-1}) were observed at the stream gauging station above the inlet to Osoyoos Lake in 1976 and 1977, respectively. The annual mean discharges in the tributaries, Shingle and Ellis Creeks, observed in 1978, were 23 cfs (0.65 m^3 sec^{-1}) and 22 cfs (0.62 m^3 sec^{-1}), respectively.

The flow regime in the Okanagan River is characterized by high discharges during spring freshets and early in summer, and by low discharges in fall and winter. The division of the hydrological year, involving the two following periods: April to September and October to March is used to describe the phosphorus load variation. The arithmetic mean loads and their 95% confidence limits calculated for these two periods over all years of the study (Table 1), yield a quantity which is called annual-seasonal variation.

The annual-seasonal variation of phosphorus loads was not significant, at the 95% level, below the outlet from Okanagan Lake. The overall mean is used, therefore, to represent the amounts of phosphorus exported from this lake during the period from 1976 to 1980. The phosphorus transport into and out of Skaha Lake shows a different pattern. The phosphorus outputs from this lake, during 1976 to 1979, exceeded inputs and were significantly higher in the periods April to September than in the periods October to March. During the October to March periods, the loads are low and the phosphorus inputs and outputs are almost in balance.

The annual-seasonal variation is very significant at the station located above the inlet to Skaha Lake (Table 1). The phosphorus loads at this station are significantly higher during the April to September periods than during the October to March periods.

The relative contribution of variable sources to the phosphorus load carried by the Okanagan River to Skaha Lake is illustrated on the following example. The estimated loads in the effluent from the Penticton waste treatment plant, based on the report by Houghton (3), was 14.4 lb day^{-1} (6.53 $\pm$ 3.4, 95% confidence limits, kg day^{-1}), in 1977. The annual mean loads and their 95 percent of confidence limits from the tributaries Shingle and Ellis Creek (11) were 8.69 lb day^{-1} (3.94 $\pm$ 1.69 kg day^{-1}), and 11.29 lb day^{-1} (5.12 $\pm$ 2.0 kg day^{-1}), respectively, during the period from March 1977 to October 1978. The output of phosphorus from Okanagan Lake, during these two years, was 22.6 lb day^{-1} (10.25 + 1.38 $\pm$ kg day^{-1}). These estimates indicate

TABLE 1 - Annual Seasonal Variation of Phosphorus Loads

Sampling Period		Observations	Arithmetic Mean lb day^{-1}	(kg day^{-1})*
		Below Okanagan Lake Outlet		
1976-1980	April to September	--	--	NS
	October to March	--	--	NS
	Overall	203	22.60	(10.25 ± 1.38)
		Above Skaha Lake Inlet		
1976-1979	April to September	109	54.83	(24.87 ± 4.08)
	October to March	73	35.49	(16.10 ± 2.07)
		Below Skaha Lake Outlet		
1976-1979	April to September	100	43.89	(19.91 ± 3.29)
	October to March	63	79.85	(36.22 ± 7.80)
		Above Osoyoos Lake Inlet		
1977-1980	April to September	--	--	NS
	October to March	--	--	NS
	Overall	253	197.24	(89.47 ± 49.47)

Note: NS = difference not significant at 95% level

* precision in 95% confidence limits calculated in SI units

that diffuse sources contribute approximately three times more than the waste water treatment plant to phosphorus transport to Skaha Lake.

Diffuse sources from the agricultural land, and particularly the irrigation return flow from vineyards and orchards below Oliver, contribute substantially to the further increase in phosphorus transport to Osoyoos Lake. The contribution of the load from the Oliver waste water treatment plant is small. For example, the annual mean load of phosphorus from this plant was 4.2 lb day^{-1} (1.9 ± 0.3 kg day^{-1}) in 1977. The overall mean load shown in Table 1 indicates that very large amounts of this nutrient are transported into Osoyoos Lake. The majority of these amounts come from diffuse sources (11).

A graphical representation of phosphorus loads estimated in 1970 and in 1980 and their comparison with the loading rates proposed by

Vollenweider (5) are shown in Figure 2. The surface loads of phosphorus, calculated as an average for the period of the present study are 3.57 and 12.49 lb acre^{-1} yr^{-1} (0.4 and 1.4 g m^{-2} yr^{-1}) to Skaha and Osoyoos Lakes, respectively.

These loading conditions place Skaha Lake on the permissible loading, and Osoyoos Lake above the critical loading curves in the diagram of the phosphorus - mean depth/hydraulic residence time relationship.

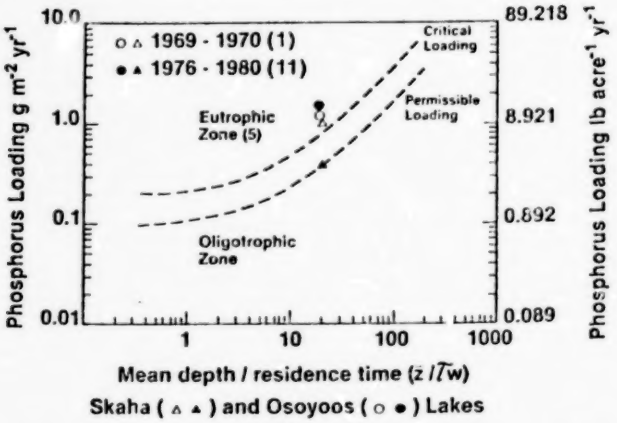

FIG. 2. - The relationship between trophic state, mean depth ($\bar{z}$), residence time (τ_w) and surface loading (grams/square metre/yr) of total phosphorus in Skaha and Osoyoos Lakes.

CONCLUSIONS

The differences between the phosphorus loads estimated during the periods from 1970 to 1980 indicate the presence of decreasing phosphorus inputs into Skaha Lake, but increasing inputs into Osoyoos Lake.

The decline of phosphorus loads into Skaha Lake is consistent. The major reduction of loads, approximately 5.5 times between the two study periods, is in the effluent from the Penticton waste water treatment plant. The excessive rate of the surface loading to Skaha Lake of 8.92 lb acre^{-1} yr^{-1} (1 g m^{-2} yr^{-1}), in 1970, is reduced to the permissible rate of 3.57 lb acre^{-1} yr^{-1} (0.4 g m^{-2} yr^{-1}) in 1980. However, the reduction in phosphorus loads is not apparent below the outlet from Skaha Lake. The phosphorus loadings of 12.49 lb acre^{-1} yr^{-1} (1.4 g m^{-2} yr^{-1}) into Osoyoos Lake estimated in 1980, remains in the same category of the critical loading rate found in 1970.

Diffuse sources combined with high discharges in the Okanagan River have the major effects on phosphorus loads into and out of Skaha Lake and into Osoyoos Lake.

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